SEASONAL OCCURRENCE AND SIZE DISTRIBUTION OF POSTLARVAL BROWN AND WHITE SHRIMP NEAR GALVESTON, TEXAS, WITH NOTES ON SPECIES IDENTIFICATION [1]

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ABSTRACT

Postlarvae of the genus *Penaeus* were collected at the entrance to Galveston Bay, Tex., over a 4-year period and along Galveston Island's beach during a 1-year period. Postlarval brown shrimp, *P. aztecus*, and white shrimp, *P. setiferus*, were the predominant penaeids caught. Morphological characters, seasonal size differences, and occurrence of juveniles in adjacent nursery areas were used to identify these species. Seasonal occurrence, size distribution, and measures of relative abundance are given for postlarvae of the two species. The uniformity in size of postlarvae from collections along the beach and at the bay entrance indicated that small shrimp do not grow much when they are along the beach.

Shrimp are the most valuable marine fishery resource of the Gulf of Mexico, where commercial landings annually exceed 170 million pounds and are valued at nearly $60 million. Many aspects of the biology and early life history of these crustaceans have been examined; however, the factors causing fluctuations in their abundance must be better defined before optimum management of the shrimp fishery can be realized.

The early life histories of commercially important species of the genus *Penaeus* inhabiting the northwestern Gulf of Mexico are similar. Each spawns in offshore waters, where the planktonic larvae hatch after several hours. During ensuing weeks, the larvae pass through a series of metamorphoses and reach near-shore areas as postlarvae. The young shrimp grow rapidly after moving into estuarine nursery areas, and return to offshore waters to complete their life cycle.

As Bearden (1961) has pointed out, the postlarvae that reach inshore waters represent the success of the spawning season and, after several months of growth, will make up the bulk of the commercial shrimp catch for a given year. Baxter (1963) has shown that systematic sampling of postlarvae entering the major nursery areas can provide an index that is useful for predicting the subsequent abundance of juvenile and adult shrimp on inshore and offshore fishing grounds.

The objectives of this report are to describe trends in the seasonal abundance and size composition of commercial shrimp postlarvae near Galveston Island, and to evaluate the use of seasonal differences in their body lengths as an aid in identifying the various species. Also examined is the question: Do young shrimp use the surf zone as a nursery area? The results of this 4-year study form a basis for current research on the biology and dynamics of the postlarval phase of commercial shrimp populations in the Gulf of Mexico.

SAMPLING PROCEDURE

Studies of postlarval shrimp began as part of a developing investigation of the life history of penaeid shrimp outlined in detail by Kutkuhn (1963). Knowing that shrimp reach shore as postlarvae and

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enter nursery areas through tidal passes, we established a sampling station at the entrance to Galveston Bay in November 1959. Additional stations along Galveston Island's Gulf beach were added later.

GALVESTON ENTRANCE

The initial sampling site was on the south side of the entrance to Galveston Bay (station A, fig. 1),

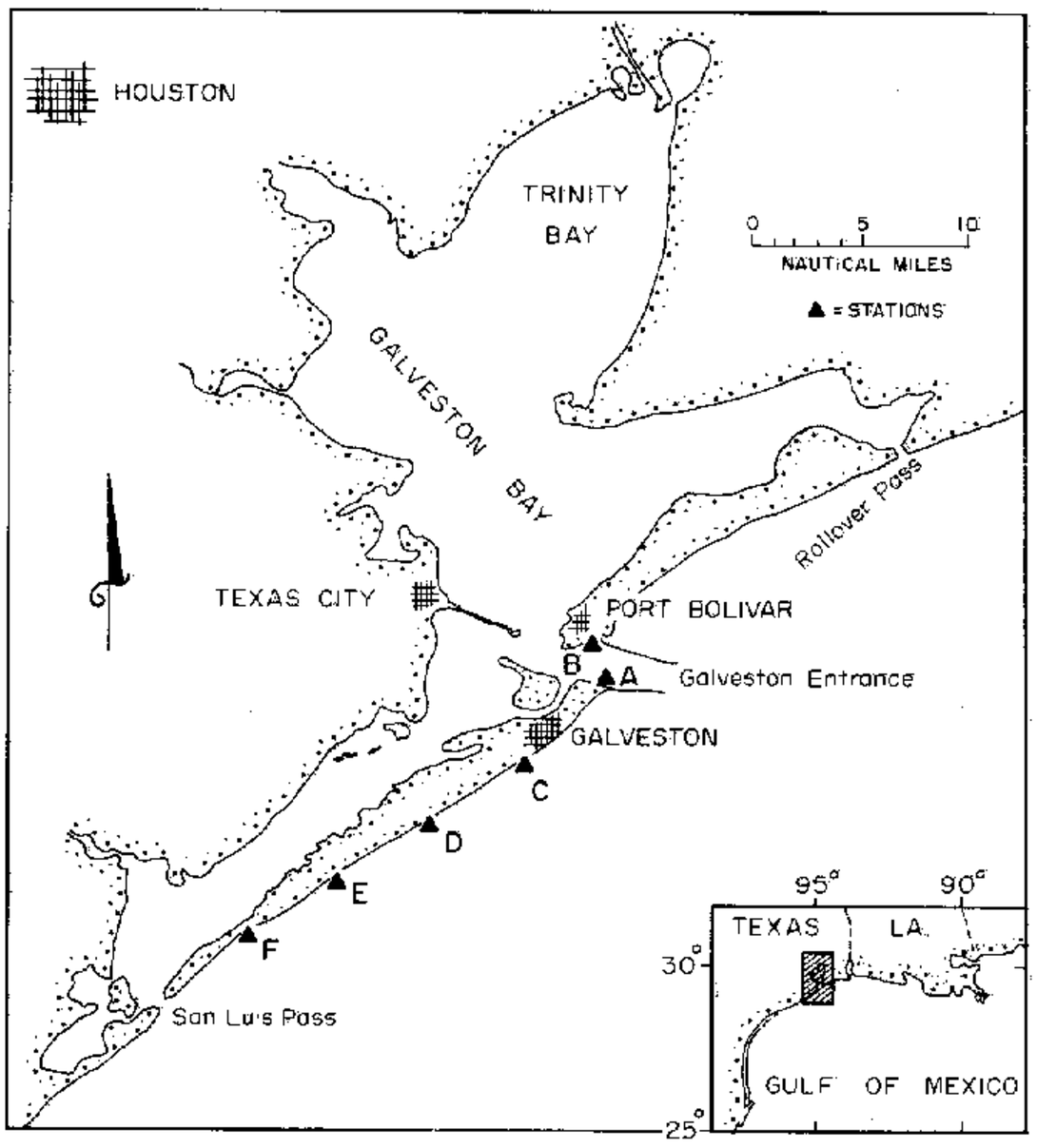

FIGURE 1.—Galveston Island and environs, showing sampling stations.

where we collected postlarval shrimp twice each week. This location was not suitable as a sampling station after Hurricane Carla in September 1961. Thereafter, semiweekly samples were obtained from station B, near the base of the north jetty. Bottom materials at both stations consisted of well-compacted sand.

Collections of postlarvae were made with a 5-foot, hand-drawn beam trawl fitted with a plankton net at its cod end (Renfro, 1963). The wings of the trawl consisted of nylon netting having 50 holes per square centimeter. We believe that escapement of postlarval shrimp was negligible, because most collections contained an abundance of organisms more minute than the smallest postlarvae captured. To test whether or not large shrimp were evading the small beam trawl we towed a fine-mesh, 20-foot seine on several occasions. A standard procedure was followed during each collection. One end of a 150-foot line was tied to a stake driven into the sand at the water's edge. The collector held the free end of this line in one hand and the bridle of the trawl in the other and pulled the gear along the bottom in a semicircular path from the shoreline.

GULF BEACH

Collections of postlarval shrimp were made twice each month between April 1960 and April 1961 at 5-mile intervals along Galveston Island's 25-mile beach (stations C, D, E, and F, fig. 1). The same beam trawl was used at beach stations, but because of the surf, the sampling procedure was altered from that used at stations A and B. The collector waded a measured 75 yards directly offshore, set the gear, and towed it back to shore. Computations of bottom areas sampled were based on distance towed and the dimensions of the net.

At all stations we made meteorological and hydrographic observations. Those that we consider to be pertinent, namely water temperature, salinity, and tidal stage, are listed in appendix tables 1 and 2 along with the numbers of postlarval brown and white shrimp collected on each sampling date.

SEASONAL OCCURRENCE

GALVESTON ENTRANCE

Postlarval brown shrimp, *P. aztecus* Ives, appeared at Galveston Entrance and migrated to the nursery areas within Galveston Bay at about the same time

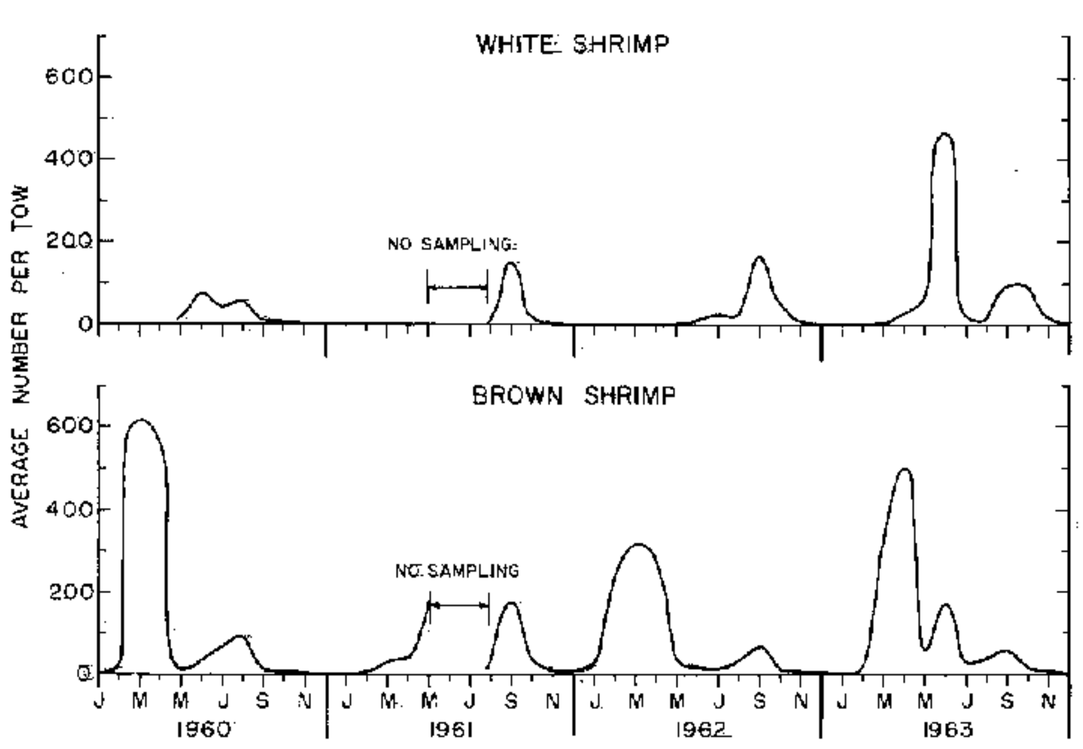

FIGURE 2.—Seasonal abundance of postlarval brown and white shrimp at Galveston Entrance, 1960–63.

during each year of the study (fig. 2). The greatest numbers occurred in the spring; usually peak abundance was reached between mid-March and mid-April. Following the spring peak, comparatively few postlarvae were caught until about mid-June. Thereafter, the number of postlarvae in the collections increased through July and reached a second peak in August or September. In each year, the numbers of brown shrimp postlarvae present at Galveston Entrance diminished rapidly after the second peak and remained low throughout the winter. During 1961, peak abundance appeared to develop in late April and early May, but because sampling was suspended from May 8 to August 11, the actual time of the peak for that year is unknown.

The first postlarval white shrimp, *P. setiferus* (Linnaeus), were taken in early May of each year at Galveston Entrance (fig. 2). Seasonal distribution of postlarval white shrimp suggests that two peaks in abundance may occur each summer and that the relative strength of these peaks is variable.

GALVESTON ISLAND BEACH

Trends in seasonal occurrence of postlarval brown and white shrimp at Galveston Island beach stations were similar to those at Galveston Entrance stations (table 1). Brown shrimp postlarvae were numerous in mid-April 1960, from late June through August, and again during April 1961. In contrast to Galveston Entrance, a few brown shrimp postlarvae were present along the beach during late December and January. In 1961 brown postlarvae did not appear in significant numbers until early March. Postlarval white shrimp were caught in beach samples from mid-May through November 1960 and were most abundant from late June through July. None was taken from December 1960 through April 1961.

Samples of postlarvae were collected along Galveston Island beach to determine if young shrimp use the littoral zone along beaches as nursery areas. Should they use this zone, advanced stages of postlarval shrimp could be expected in collections from beach stations. Agreement as to general size of postlarvae from the beach and from Galveston Entrance (table 2), indicates, however, that postlarvae spend little time in the beach area. Repeated tows with a fine-mesh seine at beach stations caught no shrimp larger than those taken in the beam trawl.

TABLE 1.—*Average monthly densities of postlarval shrimp at Galveston Entrance and Galveston Island beach stations, April 1960–61*

[Figures represent the average number of postlarvae per 100 m.² of bottom in 7 to 12 collections each month]

Month	Brown shrimp postlarvae		White shrimp postlarvae	
	Galveston Entrance	Gulf beach	Galveston Entrance	Gulf beach
1960:				
Apr.	294	52	0	0
May	2	15	6	9
June	23	54	40	52
July	35	234	14	133
Aug.	51	153	29	26
Sept.	0	3	2	39
Oct.	0	3	0	3
Nov.	0	3	0	3
Dec.	1	8	0	0
1961:				
Jan.	0	1	0	0
Feb.	1	1	0	0
Mar.	13	70	0	0
Apr.	72	760	1	0

TABLE 2.—*Mean total lengths of postlarval shrimp collected concurrently along the Galveston Island beach and in Galveston Entrance, 1960–61*

[Figures in parentheses indicate number of specimens measured]

Month	Brown shrimp postlarvae				White shrimp postlarvae			
	Beach		Entrance		Beach		Entrance	
	Mm.		*Mm.*		*Mm.*		*Mm.*	
1960:								
Apr.	11.4	(82)	11.5	(167)				
May	10.4	(52)	10.5	(34)	6.3	(47)	6.4	(51)
June	8.9	(113)	8.8	(101)	5.9	(115)	6.5	(149)
July	8.7	(181)	8.4	(155)	7.2	(186)	6.3	(129)
Aug.	8.6	(241)	8.5	(146)	6.7	(177)	6.3	(153)
Sept.	9.5	(25)	10.0	(10)	7.5	(77)	7.1	(35)
Oct.	10.1	(27)	11.0	(4)	6.8	(24)	7.2	(10)
Nov.	10.9	(23)	11.2	(6)	7.5	(23)	7.5	(8)
Dec.	11.9	(59)						
1961:								
Jan.	11.7	(6)						
Feb.	11.0	(11)	12.0	(6)				
Mar.	11.6	(165)	11.6	(86)				
Apr.	11.3	(200)	11.6	(112)				

IDENTIFICATION AND SEASONAL SIZE DISTRIBUTION

Of the three commercially important species of the genus *Penaeus* in the northern Gulf of Mexico, the pink shrimp, *P. duorarum*, is the least abundant. Small numbers of adult pink shrimp are commonly caught off Galveston Island (15–20 fathoms), but landing data compiled by the Bureau of Commercial Fisheries Branch of Statistics[3] included no pink shrimp in landings of 3.7 million pounds taken from Galveston Bay during 1960–63. A few pink shrimp, however, may have been landed and reported as

[3] "Gulf Coast Shrimp Catch by Area, Depth, Variety, and Size," Annual Summaries, 1960–63.

brown shrimp. Of about 47,000 juvenile shrimp examined from Galveston Bay bait landings between January 1960 and December 1963, only 17 (less than 0.04 percent) were pink shrimp. In earlier work, the second author (1958–59) found no pink shrimp among more than 10,000 juvenile penaeid shrimp taken from upper Galveston Bay. Although postlarval pink shrimp obviously occur in the Galveston area they evidently are scarce; all postlarvae we caught were classified as brown or white shrimp.

MORPHOLOGY

No single criterion is sufficient to distinguish brown and white shrimp postlarvae, but they can be separated by taking into account various morphometric characters, relative size, and seasonal occurrence as juveniles in the estuary. Morphological and morphometric differences between postlarval brown and white shrimp provided by Pearson (1939) and Williams (1959) are sufficient to separate these species during most seasons. Williams, working with shrimp from North Carolina, developed a provisional key to early postlarvae. He stated that the tip of the rostrum and the extended third pereiopod on postlarval white shrimp do not extend to the distal edge of the eye. Conversely, in the brown shrimp, both the tip of the rostrum and extended third pereiopod reach to or beyond the edge of the eye. In postlarvae from the Galveston area, these characteristics suffice only to separate postlarval white and brown shrimp with a total length of 10 mm. or less, whereas Williams was able to use them in North Carolina for separating postlarvae up to 12 mm. total length.

OCCURRENCE ON GALVESTON BAY NURSERY GROUNDS

According to our records, brown shrimp are the only postlarval *Penaeus* that enter Galveston Bay during the first 4 months of the year. This observation agrees with findings from several previous studies conducted in the bay. Renfro (1959) found only brown shrimp postlarvae and juveniles (17 mm. and above) in upper Galveston Bay during April and May 1959. Gunter (1960) also found brown shrimp to be the only species at the juvenile stage present in Galveston Bay during April and May 1960. Later reports by biologists of the Texas Game and Fish Commission corroborate the observations of Renfro and Gunter (Pullen, 1962).

By June, advanced postlarval and early juvenile white shrimp (18–28 mm.) become abundant in Galveston Bay, and both brown and white shrimp are present throughout the summer (Gunter, 1960). Additional evidence regarding the identity of the winter and early spring postlarvae was provided in 1960 when 1,200 postlarvae, taken on April 12 at Galveston Entrance, were brought into the laboratory to be reared. All that grew to identifiable size (150) were brown shrimp.

SEASONAL SIZE DISTRIBUTION

The size of postlarvae caught at the entrance to Galveston Bay provides a strong clue to species identity during some seasons (fig. 3). During the winter, the total length of brown shrimp postlarvae ranged from 10 to 14 mm. and averaged 12 mm. (fig. 3). Beginning in May of each year, a second group of much smaller (6.0 to 8.0 mm.) postlarvae appeared in the samples. These shrimp possessed the external morphological characteristics of postlarval white shrimp described by Pearson (1939) and Williams (1959). By late June the length distributions of the two groups of postlarvae began to overlap. The modes of the length distribution of brown postlarvae decreased, possibly because adult brown shrimp were spawning near shore in spring and summer, or because warm water temperatures increased the developmental rates of larvae. During the same period, some white shrimp postlarvae as long as 10.5 mm. entered the estuary. Most of the larger postlarvae, however, exhibited the characteristics ascribed to brown shrimp by Williams (1959). The overlap in length distributions persisted throughout the summer, but the mean length of brown shrimp postlarvae always exceeded that of white shrimp in the same samples (fig. 3). In the latter part of each year, the modal length of brown shrimp postlarvae increased, and by October in some years the overlap in length distributions had ended.

Postlarvae of brown and white shrimp caught at beach stations and at Galveston Entrance were of similar sizes (table 2). The total length of postlarval brown shrimp ranged from 8.5 to 12.0 mm. (mean, 11.5 mm.). White shrimp ranged from 5.0 to 9.5 mm. (mean, 7.0 mm.). No significant difference existed among the mean lengths of postlarvae taken at the various beach stations on the same day.

SUMMARY

Collections of penaeid postlarvae were obtained semiweekly at Galveston Entrance over a 4-year

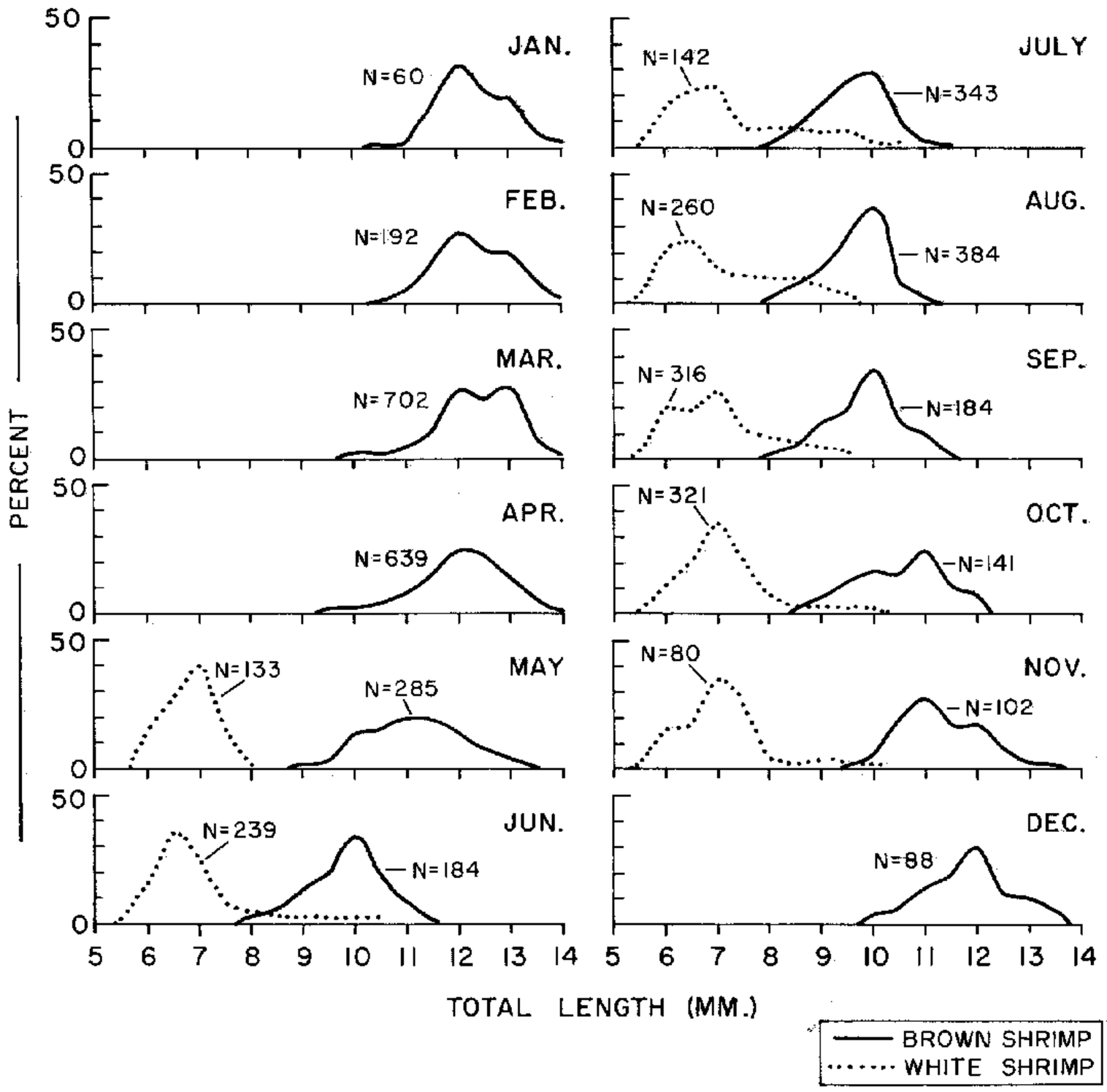

FIGURE 3.—Seasonal size distribution of postlarval brown and white shrimp at Galveston Entrance, 1960–63. (N indicates sample size.)

period and twice each month at four stations along Galveston Island's Gulf beach for 1 year.

Postlarval brown shrimp were collected at Galveston Entrance from February until mid-December of each year. At Galveston beach stations, they were found throughout the year but in smaller numbers during the winter. Numbers of brown shrimp postlarvae reached an annual peak between mid-March and mid-April.

Postlarval white shrimp were first caught at Galveston Entrance and along the beach in May and were most abundant through the summer.

Postlarvae of brown and white shrimp were separated by morphometric characters and by the seasonal occurrence of each species in the adjacent estuary. The brown shrimp was the only *Penaeus* species at the postlarval stage present along the Galveston Island beach and at the entrance of Galveston Bay from December through April. All individuals were relatively large (11 mm. or longer) during this period. After April, their average size decreased, remained relatively small throughout the summer, and then increased again in the fall. White shrimp postlarvae first appeared in May at lengths much shorter than those of brown postlarvae in the same collections; the total lengths of the majority ranged from 6.0 to 8.0 mm. During the summer, the length distributions of postlarvae of brown and white shrimp overlap in the 8- to 10-mm. length range. The two species at this stage of development may, however, be separated by the morphological characteristics described by Pearson (1939) and Williams (1959). At times, the largest white shrimp postlarvae in a sample were longer than the smallest postlarvae of brown shrimp, but the mean lengths of the white postlarvae were always less than those of the brown postlarvae.

The similarity of mean lengths of postlarvae collected along the beach and at Galveston Entrance suggests that significant growth does not occur along the beaches and that the surf zone is not an important nursery area for small shrimp.

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APPENDIX

TABLE A-1.—*Numbers of postlarval shrimp collected and associated hydrographic observations, Galveston Entrance, 1959–63*

Date	Time	Postlarvae per standard tow		Water temperature	Salinity	Tidal stage[1]
		P. aztecus	*P. setiferus*			
		Number	*Number*	°C.	o/oo	
1959:						
Nov. 9	1000	0	0			
16	1330	0	0			
Dec. 11	1500	0	0			
18		0	0			
21		0	0			
31		0	0			

See footnote at end of table.

TABLE A-1.—*Numbers of postlarval shrimp collected and associated hydrographic observations, Galveston Entrance, 1959–63*—Continued

Date	Time	Postlarvae per standard tow		Water temperature	Salinity	Tidal stage[1]
		P. aztecus	*P. setiferus*			
		Number	*Number*	°C.	o/oo	
1960:						
Jan. 8		1	0			
13	1530	4	0	15.5	25.3	HWS
15	1100	0	0	14.9	25.3	F
19	1400	0	0	9.8	9.4	E
22	0900	12	0	9.0	23.9	F
25	1100	1	0	10.2	26.0	F
28	1115	1	0	12.5	18.3	F
Feb. 1	1300	1	0	12.2	28.4	
5	1100	0	0	10.2	14.0	F
9	0900	2	0	15.0	31.2	
11	0930	0	0	13.0	27.3	E
16	1100	3	0		16.9	
18	1415	3	0	12.5	12.1	E
24	1000	2	0	10.0	23.6	F
25	1500	2	0	12.0		F
Mar. 1	1345	0	0	10.0	28.6	F
3	1405	0	0	10.5	11.1	E
7	1620	6	0	10.0	26.2	F
11	1330	53	0	13.0	15.9	E
15	1400	39	0	15.0	25.4	
18	1420	72	0	14.2	23.2	E
22	1400	39	0	18.5	28.9	F
28	1100	4,710	0	20.8	26.2	
Apr. 1	1120	3,680	0	19.5	26.9	F
5	1045	86	0	18.2	16.1	F
8	0830	5	0	18.5	25.7	LWS
12	1330	1,000	0	21.0	30.1	F
15	0900	100	0	23.5	28.2	F
19	1115	9	0	22.2	24.1	F
21	1330	50	0	26.0	24.0	HWS
26	1515	56	0	27.0	24.0	F
29	1330	3	0	24.0	23.8	E
May 3	0830	0	0	22.0	22.2	F
6	1400	4	0	24.0	23.0	F
10	0900	6	4	22.2	24.2	E
13	1330	1	1	24.2	29.0	F
17	0845	2	2	24.8	30.5	F
20	0900	9	12	25.6	29.5	F
23	0830	7	82	25.4	27.8	E
26	1545	5	6	29.0	26.9	E
31	1500	0	1	31.2		HWS
June 3	1400	0	12	30.7	27.2	LWS
6	1030	0	23	29.0	29.3	F
9	1030	0	0	29.5	32.5	F
14	0830	0	8	28.0	31.2	F
17	0900	167	428	28.4	31.8	E
21	0930	1	6	29.0	32.7	F
24	1515	65	25	28.2	32.5	F
27	1400	108	60	30.0	31.1	F
30	0900	38	98	30.0	26.8	F
July 5	1500	74	148	31.9	31.4	LWS
8	1445	4	1	33.2	25.8	F
12	0930	61	28	30.0	29.4	E
15	1300	30	6	32.0	25.8	E
19		18	71	29.0	29.6	F
21	1330	73	35	32.0	31.3	F
25	0940	241	21	30.0	35.5	F
29	1410	8	1	34.0	28.0	E
Aug. 1		148	117	29.5	35.6	E
5	1345	21	27	32.0	36.1	F
9	1330	16	24	33.3	34.2	F
12	1430	0	4	29.5	26.3	E
15	1330	257	202	31.0	33.3	E
19	1600	1	2	30.5	27.1	E
22	1000	81	20	28.0	27.8	E
25	0915	306	77	29.5	28.8	LWS
29	1220	8	3	29.0		F
Sept. 2	1130	4	9	31.4	26.5	F
6	1400	3	10	32.0	24.6	F
9	1010	0	3	30.1	23.2	E
12	0900	0	1	27.0	25.9	
16	0930	0	0	27.0	21.3	E
20	0950	1	4	29.0	27.0	E

See footnote at end of table.

TABLE A-1.—*Numbers of postlarval shrimp collected and associated hydrographic observations, Galveston Entrance 1959–63*—Continued

Date	Time	Postlarvae per standard tow		Water temperature	Salinity	Tidal stage[1]
		P. aztecus	*P. setiferus*			
		Number	*Number*	°C.	o/oo	
1960:—Continued						
Sept. 23	1310	1	2	32.0	27.8	LWS
27	1400	2	5	28.0	24.1	E
30	1615	0	0	30.0	26.5	LWS
Oct. 3	1400	0	0	28.0	28.6	F
7	1100	2	3	27.2	24.6	E
11	1400	0	1	30.0	26.7	E
14	1400	0	2	25.8	28.6	F
17	0845	2	3	25.0	27.0	F
20	0930	0	0	21.0	16.3	E
25	0900	0	0	23.5	27.3	F
28	1415	0	1	27.0	25.5	E
31	1430	0	1	21.3	17.1	E
Nov. 3	1415	1	5	24.0	20.0	F
7	1430	0	0	21.0	22.9	F
10	1600	0	0	12.5	17.9	E
15	1145	1	2	24.0	26.2	F
18	1415	0	0	18.5	26.9	F
21	1630	0	0	18.0	24.9	F
25	1430	1	0	20.0	11.2	E
28	1545	3	1	22.5	24.5	F
Dec. 2	1545	0	0	16.0	27.8	F
6	1530	0	0	19.0	27.1	F
9	1500	1	0	15.5	29.5	F
13	1545	0	0	13.5	31.0	E
16	1445	6	0	13.0	19.2	E
19	1440	0	0	12.0	-------	E
22	1500	0	0	12.2	25.4	E
27	1100	0	0	13.0	19.4	F
29	1145	0	0	12.5	11.1	F
1961						
Jan. 3	1330	0	0	11.8	14.4	E
6	1135	0	0	12.2	24.9	F
10	1530	0	0	13.0	-------	E
13	1405	0	0	12.4	8.3	E
16	1115	0	0	12.5	15.2	E
20	1500	0	0	14.8	7.8	E
25	1410	0	0	10.2	26.8	F
27	1340	0	0	8.0	12.7	E
30	1340	0	0	11.8	11.9	E
Feb. 3	1420	0	0	13.0	13.8	E
7	1430	0	0	11.0	10.8	E
10	1415	0	0	13.0	24.4	F
17	1405	4	0	19.2	28.6	E
21	1420	0	0	15.0	7.6	E
24	1100	0	0	17.0	8.9	E
27	1115	2	0	15.0	10.9	F
Mar. 3	1350	6	0	19.0	30.2	E
6	1510	5	0	19.4	21.8	E
10	1520	2	0	17.8	26.7	E
14	1430	1	0	19.2	26.7	F
17	1400	97	0	20.5	26.7	E
21	1520	28	0	19.7	25.9	E
27	1440	2	0	27.4	25.8	E
31	1040	42	0	20.1	18.2	E
Apr. 5	0845	6	0	19.2	25.3	F
7	1515	12	0	19.5	30.9	E
11	1045	4	0	19.1	29.2	F
17	1555	209	0	20.0	27.8	E
21	1600	10	0	23.0	29.4	E
25	1600	3	0	24.0	25.6	F
28	1550	2	0	24.1	15.0	E
May 2	1355	51	0	25.8	16.6	E
8	1500	889	10	26.9	19.1	E
		—SAMPLING INTERRUPTED—				
Aug. 11	1720	0	0	31.7	30.5	E
15	1410	5	15	33.8	30.3	E
17	0845	6	11	29.8	28.4	E
21	1400	24	10	31.5	20.6	E
24	0915	54	6	29.8	24.6	E
28	1400	8	0	29.8	22.2	F

See footnote at end of table.

TABLE A-1.—*Numbers of postlarval shrimp collected and associated hydrographic observations, Galveston Entrance, 1959–63*—Continued

Date	Time	Postlarvae per standard tow		Water temperature	Salinity	Tidal stage[1]
		P. aztecus	*P. setiferus*			
		Number	*Number*	°C.	o/oo	
1961:—Continued						
Sept. 1	1415	520	544	30.9	24.3	E
6	1415	65	44	33.9	22.3	E
		—HURRICANE CARLA—				
25	1200	5	0	32.0	17.2	F
27	1510	4	0	34.0	17.2	F
Oct. 2	0925	2	1	29.0	18.1	F
5	0900	6	3	20.0	27.8	F
10	1005	32	1	29.0	27.3	E
12	1400	5	0	30.2	24.8	E
16	1545	61	74	24.5	27.4	E
19	1520	6	7	27.0	25.7	E
23	0925	0	0	23.5	24.7	E
25	0905	2	0	24.9	26.3	E
27	0920	144	77	20.5	28.5	E
30	1425	11	3	30.0	29.1	E
Nov. 3	1345	9	4	19.5	27.0	F
6	1520	3	0	12.0	24.0	F
9	0910	45	0	13.0	24.7	E
14	0940	13	1	19.0	23.5	E
16	0945	0	0	17.0	15.0	E
21	0940	1	0	17.5	28.7	F
24	1405	0	0	19.0	28.7	F
27	1020	4	0	21.5	27.5	E
30	0945	0	0	12.0	28.4	LWS
Dec. 5	0930	21	0	20.0	27.5	E
8	1430	0	0	16.0	27.0	F
11	0920	11	0	20.5	25.6	E
14	0920	0	0	8.5	23.1	HWS
19	0925	2	0	13.5	24.4	E
22	1400	1	0	18.0	26.3	E
26	0945	9	0	13.5	27.9	E
29	0920	0	0	10.0	24.4	E
1962:						
Jan. 2	1410	0	0	15.0	27.5	LWS
4	0925	12	0	16.0	31.2	E
9	0925	224	0	12.0	31.0	E
12	0905	5	0	−2.0	30.5	F
15	0905	0	0	6.0	29.9	E
17	1400	0	0	9.0	29.8	F
23	1410	0	0	9.0	27.7	E
26	1045	0	0	15.0	27.2	F
29	0900	0	0	10.0	25.7	LWS
Feb. 1	1550	1	0	14.0	26.5	F
6	0845	73	0	9.0	31.4	E
9	1400	34	0	22.0	29.6	E
12	1030	196	0	19.0	26.3	F
15	1400	48	0	21.0	27.6	F
19	0925	222	0	15.0	27.6	E
23	1340	53	0	22.0	22.3	E
26	0900	1,220	0	22.0	21.7	F
Mar. 1	1525	0	0	5.5	23.0	F
6	1030	40	0	12.0	23.3	E
9	1415	368	0	24.0	24.7	E
12	1100	66	0	17.5	25.5	F
16	1415	8	0	17.5	19.5	F
20	0925	506	0	19.5	26.9	LWS
23	1440	626	0	20.5	26.7	F
26	1035	140	0	19.0	22.3	F
29	1420	75	0	24.0	28.9	F
Apr. 4	0925	1,682	0	16.0	27.0	E
6	1445	234	0	23.0	25.5	E
9	0900	24	0	21.0	24.4	F
12	1445	135	0	24.0	25.3	E
17	0925	192	0	20.5	24.9	E
20	1430	44	0	27.5	24.4	F
23	0905	103	0	24.0	25.2	F
26	1400	3	0	26.0	24.6	F
May 1	1000	4	0	26.0	23.3	E
3	1425	250	0	24.0	18.0	F
7	0910	23	0	24.1	17.7	F
10	0925	7	0	25.0	23.6	F

See footnote at end of table.

TABLE A-1.—*Numbers of postlarval shrimp collected and associated hydrogfaphic observations, Galveston Entrance, 1959–63*—Continued

Date	Time	Postlarvae per standard tow		Water temperature	Salinity	Tidal stage[1]
		P. aztecus	*P. setiferus*			
		Number	*Number*	°C.	o/oo	
1962:—Continued						
May 15	0925	2	0	26.0	31.7	HWS
18	1500	0	0	27.9	24.2	F
21	0915	0	0	27.0	23.8	F
24	1500	0	0	29.0	24.7	F
29	0905	3	1	26.0	18.9	E
June 1	1430	0	2	26.0	15.7	HWS
4	0925	0	6	26.0	14.7	F
8	1510	6	0	31.5	17.9	HWS
12	0950	8	4	29.5	18.6	E
15	1100	0	0	31.5	26.8	HWS
18	0855	32	6	31.0	26.1	F
21	1423	16	28	34.0	24.4	F
26	0945	0	0	30.5	24.6	F
29	1450	6	6	32.0	23.8	E
July 2	0905	11	13	30.0	23.2	F
5	1100	17	15	33.0	19.9	F
10	0905	0	1	32.0	20.0	E
13	1410	0	0	33.0	31.5	E
16	0845	13	61	30.0	29.8	F
19	1445	48	116	34.0	33.6	E
24	0900	0	1	31.0	35.5	F
27	1410	3	4	32.5	37.4	HWS
30	0910	1	5	30.0	33.8	E
Aug. 2	1415	14	4	33.0	34.4	E
8	0900	19	2	31.0	31.4	E
10	1430	4	4	35.0	35.6	E
13	0905	0	0	30.0	34.4	E
16	1400	145	46	32.0	35.8	F
21	0915	16	29	31.0	36.1	E
24	1405	25	31	33.5	35.6	E
27	0925	76	36	29.0	36.1	E
30	1420	6	29	31.0	29.8	F
Sept. 4	0900	15	106	31.0	30.5	E
7	1410	3	10	31.0	28.6	E
10	0925	25	38	30.5	31.0	E
13	1425	2	2	33.0	31.5	F
18	0905	37	78	30.0	28.7	E
21	1505	11	42	27.0	26.8	E
24	1045	2	7	28.0	25.3	LWS
27	1410	367	1,227	26.0	27.0	F
Oct. 2	1500	24	96	29.0	27.8	F
5	1430	0	6	27.0	26.9	E
8	0920	0	17	29.5	27.0	E
11	1420	0	0	31.0	28.7	F
16	0910	0	1	29.0	30.1	E
19	1440	2	11	29.0	29.8	E
22	0845	6	150	23.0	28.8	LWS
25	1410	4	29	22.0	30.2	F
30	0905	12	46	18.0	26.5	E
Nov. 2	1505	6	13	22.0	29.2	E
5	0845	0	0	17.0	29.1	E
8	1405	1	4	20.0	29.3	E
13	0930	2	0	14.0	30.8	E
16	1445	6	0	22.0	30.9	E
19	0915	0	0	12.0	31.0	F
23	0900	0	0	16.0	29.7	E
26	0905	1	0	18.5	29.9	E
29	1450	0	0	11.0	22.9	F
Dec. 3	0845	13	1	16.5	29.1	E
6	1405	0	0	16.5	20.8	F
11	0915	0	0	16.0	30.6	E
14	1315	0	0	12.0	32.4	LWS
17	0915	0	0	9.0	31.5	F
20	1410	39	0	20.0	31.8	F
26	0905	0	0	11.0	26.3	E
28	1600	0	0	13.0	22.7	F
31	1035	0	0	11.5	28.1	E
1963						
Jan. 4	1445	0	0	15.0	29.1	F
8	0930	1	0	11.0	23.2	E
11	1430	0	0	16.0	31.3	F
14	0845	0	0	0.0	32.4	E

See footnote at end of table.

TABLE A-1.—*Numbers of postlarval shrimp collected and associated hydrographic observations, Galveston Entrance, 1959–63*—Continued

Date	Time	Postlarvae per standard tow		Water temperature	Salinity	Tidal stage[1]
		P. aztecus	*P. setiferus*			
		Number	*Number*	°C.	o/oo	
1963:—Continued						
Jan. 17	1310	0	0	9.0	29.5	F
22	0900	0	0	9.0	24.9	E
25	1430	0	0	7.0	28.5	F
28	0935	0	0	1.0	27.9	E
31	1410	0	0	15.0	25.9	F
Feb. 5	1115	0	0	12.0	29.8	E
7	1435	0	0	16.0	29.6	F
11	0940	0	0	9.0	31.5	E
14	1430	0	0	11.0	25.8	E
19	0935	0	0	8.0	27.2	E
21	1410	0	0	16.0	29.6	F
25	0930	0	0	11.0	28.7	E
28	1415	0	0	15.0	29.7	F
Mar. 5	0920	441	0	14.5	30.4	E
8	1415	16	0	16.0	30.6	F
11	0925	288	0	17.0	30.4	E
14	1400	21	0	18.0	29.0	F
19	0850	280	0	21.0	29.2	HWS
22	1425	286	0	15.0	27.4	E
25	0840	986	0	20.0	26.9	F
28	1350	114	0	27.0	25.9	HWS
Apr. 2	0958	360	0	22.5	27.6	F
5	1146	3,521	0	20.0	27.6	F
8	0925	147	0	21.0	27.6	LWS
11	1415	54	0	28.0	30.6	F
16	0910	167	0	23.8	33.0	F
19	1415	44	0	27.0	32.0	F
22	0910	103	0	25.0	28.0	F
25	1410	93	0	29.0	21.0	E
30	0855	41	3	24.0	21.6	F
May 3	1410	68	5	30.0	20.5	F
6	0910	181	272	25.0	21.7	E
9	1400	71	9	27.0	24.2	F
14	0910	10	0	26.0	28.8	F
17	1410	16	1	29.0	29.0	F
20	0950	17	2	28.0	31.3	E
23	1435	134	70	27.0	34.5	F
28	0915	29	26	27.5	32.3	F
31	1405	28	115	32.0	33.2	F
June 3	0910	381	3,407	34.0	34.8	E
6	1415	5	117	32.0	32.6	E
11	0915	6	19	30.0	30.8	F
15	0915	38	21	28.0	32.9	F
17	1410	7	18	35.0	32.3	F
20	1440	24	10	31.0	33.1	F
25	0915	882	548	29.0	29.9	F
28	1410	211	4	35.0	27.1	F
July 1	0910	16	0	30.0	31.2	F
5	1415	62	9	32.5	31.3	HWS
9	0910	59	29	30.0	31.1	E
12	1415	23	2	31.0	34.3	F
15	0910	33	0	29.0	31.8	F
18	1420	11	2	33.0	34.9	E
23	0910	32	0	31.0	33.6	F
26	1420	23	3	26.0	29.1	LWS
29	0935	14	6	31.0	36.1	E
Aug. 1	1415	7	5	34.0	35.2	E
6	0915	51	21	31.0	34.6	E
9	1415	94	30	33.5	36.5	LWS
12	0915	19	36	29.0	35.0	E
15	1430	27	26	29.5	35.2	E
20	0910	48	12	30.0	35.9	F
23	1415	93	38	35.0	36.9	E
26	0910	4	0	30.0	36.4	E
29	1430	10	5	34.0	37.1	E
Sept. 3	0930	41	28	30.0	37.6	F
6	1430	10	14	29.5	33.3	LWS
9	0910	1	18	30.0	37.1	HWS
12	1410	6	35	32.0	36.7	E
18	0910	24	264	24.0	28.2	F
20	1415	206	132	29.0	27.7	HWS
23	0935	60	94	25.0	27.4	E
26	1420	68	167	26.0	24.9	LWS

See footnote at end of table.

TABLE A-1.—*Numbers of postlarval shrimp collected and associated hydrographic observations, Galveston Entrance, 1959–63*—Continued

Date	Time	Postlarvae per standard tow		Water temperature	Salinity	Tidal stage[1]
		P. aztecus	*P. setiferus*			
		Number	*Number*	°C.	o/oo	
1963:—Continued						
Oct. 1	0910	54	177	21.0	29.3	E
4	1415	4	2	24.0	29.6	LWS
7	0910	19	141	26.0	29.5	E
10	1415	0	47	30.0	30.5	E
15	0910	6	76	26.0	31.4	E
18	1405	14	44	26.5	32.6	F
21	0915	2	14	24.0	31.7	E
24	1415	2	14	26.0	31.8	E
29	0915	10	309	21.0	31.4	HWS
Nov. 1	1505	0	0	19.5	30.7	F
4	0925	4	19	21.0	30.8	E
7	1430	0	0	25.0	30.6	E
12	0925	3	39	18.0	30.0	E
15	1410	0	0	----------	30.3	F
18	1505	17	15	26.0	31.3	F
26	1100	0	0	17.0	30.7	F
Dec. 2	1420	0	0	20.0	30.4	E
5	1415	0	0	17.0	32.5	E
10	0950	0	0	15.0	32.8	F
13	1410	0	0	9.0	29.9	F
16	0930	0	0	5.0	31.0	E
19	1430	0	0	9.0	30.3	E
24	1430	0	0	10.0	29.9	E
27	1515	0	0	18.0	31.1	F
30	1005	0	0	10.0	32.8	E

[1] F = Flood; E = Ebb; HWS = High-water slack; LWS = Low-water slack.

TABLE A-2.—*Numbers of postlarval shrimp and associated hydrographic observations, Galveston Island beach stations, 1960–61*

Date	Station	Time	Postlarvae per standard tow		Water temperature	Salinity	Tidal stage[1]
			P. aztecus	*P. setiferus*			
			Number	*Number*	°C.	o/oo	
1960:							
Apr. 14	C	----------	----------	----------	----------	----------	----------
	D	1200	18	0	21.2	29.8	HWS
	E	1245	137	0	21.5	30.2	HWS
	F	1345	161	0	22.2	30.7	E
27	C	0900	1	0	24.2	23.9	F
	D	0940	3	0	24.7	24.0	F
	E	1030	5	0	25.2	24.2	F
	F	1115	5	0	25.5	23.3	F
May 11	C	1045	0	0	23.2	30.1	LWS
	D	1130	3	0	23.6	30.3	LWS
	E	1230	4	0	23.2	30.8	F
	F	1330	3	1	23.0	31.0	F
25	C	0830	1	4	26.3	29.2	E
	D	0915	11	3	26.8	29.7	E
	E	1000	89	50	27.0	29.8	E
	F	1045	5	14	27.0	29.7	E
June 8	C	0900	2	9	28.0	32.7	F
	D	0945	3	3	29.0	33.1	F
	E	1030	6	2	29.1	33.5	F
	F	1100	2	1	29.0	33.9	F
22	C	0840	191	64	29.6	32.9	E
	D	0940	51	107	30.0	32.9	E
	E	1020	113	122	30.1	33.1	F
	F	1100	28	73	30.8	33.1	F
July 6	C	0930	6	11	29.8	31.5	LWS
	D	1000	135	90	30.8	31.9	F
	E	1030	112	168	30.6	31.3	F
	F	1200	125	62	33.0	31.7	F
20	C	0840	39	36	29.4	33.4	E
	D	0920	432	288	29.3	33.4	HWS
	E	1045	392	54	30.0	33.9	E
	F	1200	390	260	30.4	33.3	F
Aug. 3	C	0830	59	63	29.7	36.1	F
	D	0930	97	24	29.8	36.0	F
	E	1000	168	15	30.0	35.9	F
	F	1120	1	0	30.5	35.9	F
16	C	0830	10	10	28.5	--------	F
	D	0910	166	14	28.9	32.4	F
	E	1000	897	78	29.2	32.1	F
	F	1130	160	51	30.0	32.2	E
31	C	0840	10	0	29.0	27.5	F
	D	0930	20	13	29.0	29.4	F
	E	1045	28	14	30.2	--------	F
	F	1205	65	12	31.2	--------	E
Sept. 15	C	0840	6	74	27.8	25.9	F
	D	0935	8	189	28.0	25.5	E
	E	1110	3	12	28.5	25.4	E
	F	1305	2	10	31.3	25.7	E
Sept. 28	C	0845	0	2	24.0	28.1	E
	D	0930	1	1	24.0	28.2	E
	E	1200	0	0	26.0	28.6	E
	F	1040	5	2	25.0	28.6	E
Oct. 12	C	0840	0	0	27.0	28.1	E
	D	0930	1	2	27.4	28.8	E
	E	1030	1	7	27.8	28.9	E
	F	1110	6	5	28.0	29.2	E
26	C	0845	3	4	23.8	27.3	E
	D	0945	2	1	24.4	27.6	E
	E	1040	6	1	24.2	27.2	E
	F	1150	8	4	23.8	26.5	E
Nov. 9	C	1330	1	0	21.3	26.9	E
	D	1110	0	0	21.5	27.5	E
	E	1445	1	0	21.8	27.5	E
	F	1520	0	4	22.0	28.8	E
23	C	1320	0	4	19.5	25.5	E
	D	1405	1	1	20.0	27.3	E
	E	1435	14	11	19.5	25.7	E
	F	1540	6	3	20.0	25.4	F
Dec. 8	C	1405	17	0	17.0	28.2	F
	D	1435	8	0	16.5	28.1	F
	E	1515	18	0	17.0	28.6	F
	F	1600	15	0	16.5	--------	F
Dec. 21	C	1355	1	0	10.2	29.3	E
	D	1430	0	0	10.2	29.1	E
	E	1515	0	0	11.0	28.7	E
	F	1545	0	0	12.0	--------	E
1961:							
Jan. 4	C	0930	0	0	10.8	27.3	E
	D	1015	0	0	10.9	26.5	E
	E	1100	1	0	11.7	27.3	E
	F	1130	0	0	11.6	26.8	E
18	C	0930	0	0	14.5	27.9	E
	D	1030	3	0	16.0	32.7	F
	E	1115	1	0	16.5	32.9	F
	F	1200	1	0	16.0	32.4	F
Feb. 1	C	1330	0	0	13.0	26.5	E
	D	1420	0	0	13.0	24.6	E
	E	1440	0	0	14.0	24.9	F
	F	1530	0	0	14.0	24.9	F

[1] F = Flood; E = Ebb; HWS = High-water slack; LWS = Low-water slack.

TABLE A-2.—*Numbers of postlarval shrimp and associated hydrographic observations, Galveston Island beach stations, 1960–61*

Date	Station	Time	Postlarvae per standard tow		Water temperature	Salinity	Tidal stage[1]
			P. aztecus	*P. setiferus*			
			Number	*Number*	*°C.*	o/oo	
1961:—Continued							
Feb. 20	C	1320	0	0	17.4	26.9	F
	D	1400	2	0	16.9	27.4	F
	E	1435	7	0	17.2	26.9	F
	F	1500	2	0	16.8	26.8	F
Mar. 8	C	1335	14	0	18.0	28.8	E
	D	1415	50	0	16.7	28.8	E
	E	1445	18	0	17.5	29.1	E
	F	1510	138	0	17.9	29.3	E
Mar. 23	C	0900	8	0	17.9	27.2	F
	D	0937	145	0	18.4	27.2	F
	E	1020	72	0	19.0	27.4	F
	F	1037	69	0	19.8	27.4	F
Apr. 5	C	1315	141	0	20.0	29.2	F
	D	1355	217	0	19.7	27.7	F
	E	1425	1,040	0	20.0	30.7	F
	F	1455	2,662	0	----------	33.6	E
20	C	1335	173	0	24.2	29.1	E
	D	1410	254	0	24.0	29.6	E
	E	1430	196	0	23.6	30.4	E
	F	1515	850	0	24.0	31.0	E

[1] F =Flood; F =Ebb; HWS =High-water slack; LWS =Low-water slack.